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Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

CANADA'S NON-FERROUS SMELTING/REFINING INDUSTRY
HUDSON BAY MINING & SMELTING (HBMS)
TECHNOLOGICAL PROFILE

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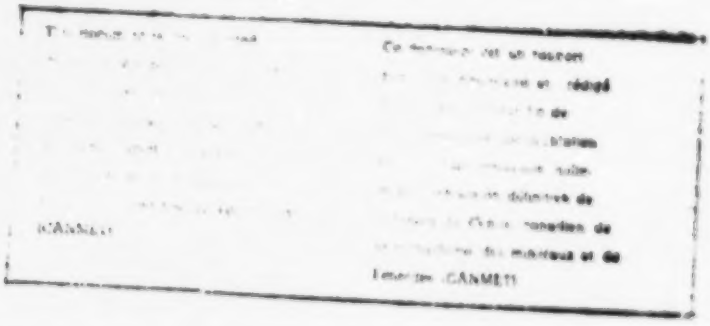
June 1985

Project: MRP-3.0.5.2.00
Mineral Processing



48 pp

MINERALS RESEARCH PROGRAM
MINERAL SCIENCES LABORATORIES
DIVISION REPORT MRP/MSL 85-48 (TR)

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ABSTRACT

HBMS' present operations, their problems and possible solutions are briefly discussed, and a detailed evaluation is carried out on those smelter modernization alternatives which appear to offer a reasonable compromise between maximizing environmental benefit and productivity, and minimizing cost and technological risk.

It has been shown that some of these modernization options appear to be adequate to achieve the dual objectives of increasing competitiveness while substantially reducing SO_2 emissions. However, the most attractive options are those that still require considerable technology development, and are therefore longer term and higher risk in nature. This is particularly true for the copper smelter modernization.

R&D initiatives have been identified to assess the technical and economic viability of these extraction refining processes for zinc and copper, and to verify their attractiveness for smelter modernization at HBMS.

It is also imperative that exploration programs be adequate to ensure that proven ore reserves can justify modernization of the HBMS smelter complex.

A concerted effort is required by industry and government to ensure that these longer term modernization alternatives can be developed and implemented within the time frame desired for the control of SO_2 emissions.

RÉSUMÉ

Le rapport porte sur les activités actuelles de la Hudson Bay Mining and Smelting Co. (HBMS), les problèmes qu'elle rencontre et les solutions pour y remédier. Il présente une appréciation détaillée des propositions concernant la modernisation de la fonderie qui semblent offrir un compromis acceptable entre l'optimisation des avantages environnementaux et la productivité et la réduction au minimum des risques technologiques et des coûts.

On a démontré que certaines de ces options de modernisation semblent se prêter à la réalisation d'un double objectif, soit l'accroissement de la compétitivité tout en réduisant de façon substentielle les émissions de dioxide de soufre (SO_2). Cependant, les propositions les plus intéressantes sont celles qui requièrent encore un développement technologique considérable et qui requièrent encore un développement technologique considérable et qui, par conséquent, présentent des risques et doivent être réalisées sur une base à plus long terme. Cette remarque s'applique en particulier dans le cas de la fonderie de cuivre.

On a identifié les initiatives de R-D afin de permettre la viabilité technique et économique de ces méthodes de raffinage du zinc et du cuivre et la vérification des avantages qu'elles présentent relativement à la modernisation de la fonderie de la HBMS.

Il est également nécessaire que les programmes d'exploration soient adéquates de façon à assurer que les réserves prouvées de minerai puissent justifier la modernisation du complexe de fonderie de la HBMS.

L'industrie et le gouvernement devront unir leurs efforts pour assurer la planification et la réalisation de ces options de modernisation à plus long terme dans les délais prévus pour le contrôle des émissions de dioxide de soufre (SO_2).

1. INTRODUCTION

This report is one in a series of reports which will attempt to assess the international competitiveness of Canada's non-ferrous smelting industry and recommend strategies for improving the industry's competitive position, while simultaneously providing acceptable methods for reducing SO_2 emissions. The report provides the following information:

- A brief description of HBMS' present operations, their problems and possible solutions;
- A brief description of the proposed modernization alternatives and their advantages and disadvantages.
- An outline of the methodology used for comparing the modernization alternatives to the present operations (base case).
- An assessment of the impact of the modernization alternatives on capital and operating costs and smelter/refinery outputs, revenues and SO_2 emissions.
- An evaluation of the proposed alternatives and recommendations on the R&D initiatives considered essential to the development of the technologies, and to the assessment of their technical and economic viability and ultimately the future viability of HBMS Flin Flon operations.

2. PRESENT OPERATIONS

The milling and smelting complex of Hudson Bay Mining and Smelting Ltd. at Flin Flon remains substantially as it was originally conceived and constructed in the early 1930's, except for plant improvements and additions which have been introduced over the past fifty years. In 1928 construction of surface plant and townsite was begun at Flin Flon, and on the Hydro Plant at Island Falls, Saskatchewan, fifty six miles northwest of Flin Flon. Also in 1928 the railway was extended to Flin Flon from The Pas.

The zinc and copper plants began operation before the end of 1930, and were increased in capacity during the second World War to about 55,000 metric tons of blister copper per year. In 1951 a fuming furnace was installed to recover zinc from copper smelter slag. In more recent years production capacity has been further increased to about 65,000 tonnes per year (mty) of blister copper and 69,000 mty of zinc, and this is the level of production assumed in the present study. HBMS directly employed about 2300 people in its plants and mills before 1982, since when it has pared its workforce by about 400 through attrition and early retirement. In addition to those directly employed the company provides indirect employment in mines supplying custom concentrates to the smelter, and in services to the people in the area.

A flowsheet of the present smelter complex is shown in Figure 1.

2.1 Mining/Milling

The original massive ore body at Flin Flon has yielded about 60 million metric tons of ore over the last 54 years and mineralization is extensive in the Flin Flon region. However, aside from the original deposit at Flin Flon, subsequent ore bodies in the area have been generally of much smaller size. During 1982 about ten mines supplied feed to the HBMS metal extraction complex. Of the ten mines six belong to HBMS. The remainder are independently owned and sell their concentrates to HBMS.

Historically HBMS has maintained 9-13 years ore reserves. An HBMS ten year ore budget, covering the years 1983 to 1992, based on present rates of exploration expenditure, shows a declining supply of ore from HBMS mines, and a decreasing number of HBMS-owned mines over the budget period. This decline of HBMS mine capacity is shown to be compensated for by an increasing dependence on custom concentrate supply.

The present study ignores this uncertainty of supply and assumes that sufficient exploration effort would be expended by HBMS to ensure that the supply of copper in concentrate feed would be equally divided between HBMS-owned and custom mines. On this basis zinc in concentrate feed would also be about equally divided between HBMS and custom concentrate suppliers.

HBMS has two concentrators, one at Flin Flon and the other at Snow Lake. Each of these concentrators operates multiple circuits to accomodate the different mineralogical characteristics of ores from various mines. The Flin Flon mill has operated with four different milling circuits and the Snow Lake mill, two circuits. Conventional differential flotation techniques are used to produce selective copper and zinc concentrates. However separation of copper and zinc into their respective concentrates is not total. About 8% of the zinc remains with the copper concentrate while about 1% of the copper reports in the zinc concentrate. Gold and silver tend to report mainly in the copper concentrate, although about 10% of the gold and 5% of the silver remain with the zinc concentrate. Interlinkage of the copper and zinc smelters facilitates the recovery of copper, zinc and precious metals which end up in the "wrong" concentrate.

Overall concentrate recoveries of copper, zinc, gold and silver are 92%, 86%, 73% & 64% respectively. Zinc concentrates from both HBMS and custom mines are of saleable grade (50% Zn). However, HBMS copper concentrates are low grade (18 to 20%) and it is unlikely that HBMS mines could survive without the Flin Flon copper smelter to process them.

2.2 Copper Smelting/Refining

Copper concentrates entering the Flin Flon copper smelter are blended with sand (silica flux), and stock-piled and fresh zinc plant leach residues, dried in two kilns, then roasted in five multi-hearth roasters to burn off part of the sulphide sulphur. The partially oxidized material is charged to a single reverberatory furnace which produces a low grade (35% copper) matte.The reverb slag contains about 0.5% copper plus most of the zinc from the feed. Copper recovery is about 96%.

Matte from the reverb furnace is transferred by ladle to three Pierce Smith converters where most of the remaining sulphur and iron is oxidized to produce blister copper, which is tapped and fed to an anode furnace. Anodes are shipped to Canadian Copper Refineries Ltd. (CCR) in Montreal for electrorefining and for precious metal recovery. Converter slag is recycled to the reverberatory furnace to recover residual copper and zinc values. Sulphur dioxide gases produced in the reverb furnace and converters are cleaned in electrostatic precipitators and exhausted to atmosphere through an 825 ft high stack. Slag from the reverb furnace, containing about 7% zinc is charged to a coal-fired zinc fuming furnace. The zinc oxide fume is recovered in baghouses, and together with the copper smelter dusts and zinc dross from the zinc melting plant, is sent to a dehalogenation roaster to remove halogens prior to feeding to the zinc plant oxide leach circuit. Zinc recovery from the slag fuming plant is about 85%. Spent slag, containing about 1% residual zinc is discarded to tailings.

2.3 Zinc Extraction/Refining

Zinc is extracted at Flin Flon in a conventional roast/leach/electrowinning (RLE) plant which began operations in 1930. The process chemistry is basically the same as in modern zinc RLE plants except that there is no strong acid leach (with iron precipitation) to recover zinc from the zinc ferrite which is formed during roasting. Maximization of zinc recovery is instead dependent on the operation of the slag fuming plant, which requires that the zinc leach residue, be recycled through the copper plant.

Zinc concentrates are dried and roasted in nine multiple hearth roasters, to produce a dead roasted calcine. The calcine contains about 14% of the total input zinc as zinc ferrite, the bulk of the remainder being present as zinc oxide which is leachable in dilute acid. The zinc roasters treat about 30% of the total sulphide sulphur entering the entire copper/zinc complex and the roaster off-gases, containing up to 3% SO_2, are cleaned of dust in electrostatic precipitators prior to exhausting to atmosphere together with the copper smelter gases through the common stack.

The zinc calcine is leached in pachucas in two stages using spent electrolyte, the final pregnant solution leaving at about pH 5. The residue from leaching contains gangue minerals, zinc ferrite, minor amounts of unroasted sulphides and lead sulphate, and small amounts of silver and gold. This residue is combined with the copper concentrate feed and is dried, roasted, and then smelted in the reverberatory furnace where the precious metals transfer to the copper matte and the zinc reports to the slag to be later recovered in the slag fuming operation.

The leach solution is purified by the addition of zinc dust to remove harmful impurities and recover copper and cadmum by-products.

The purified leach solution is sent to the electrolytic

The zinc cathodes are melted in electric induction furnaces and cast into billets. Spent electrolyte is recycled to the calcine and oxide leaching circuits. However a small bleed of approximately 10% of the spent electrolyte flow is required to prevent build up of sulfate, magnesium, and chloride in the recycle solution. Stripper cells are used to reduce zinc levels to about 8 gpl in this spent electrolyte bleed stream, prior to neutralization and discharge to tailings.

2.4 RECENT PLANT IMPROVEMENTS

Additions and modifications made to the Flin Flon metallurgical complex have not, in most cases, represented a major change in the original flowsheet although most of the plant up-grading programs have contributed towards greater plant efficiency. The installation of the slag fuming plant which began operation in 1951 represents an exception to this generalization since it enabled the recovery of zinc silver and gold from otherwise untreatable zinc plant leach residues, as well as the recovery of zinc from the copper concentrates.

Typical of the more general category of improvements in recent years was the expenditure of $3M on 2 new anode furnaces and a new 22 mould casting wheel for the production of 625 lb. anodes, rather than 450 lb. blister copper slabs, thereby effecting savings in refining costs. The same program of improvements in the early 1970's included a further $3M for replacing the reverberatory waste heat boilers and adding a 15MW steam turbine. The installation of the new 825 ft. stack in 1974 was carried out to take the off-gases from both copper and zinc plants and discharge them at high velocity, to meet the new Manitoba ambient standards for ground level SO_2 concentrations. This also entailed re-designing the smelter dust removal system to improve the in plant air quality.

In 1981 improvements were undertaken to the zinc refinery. These totalled about $20M, and included $4.5M for improved hot purification and tank house operation, $5.3M for 2 new zinc roaster electrostatic precipitators, and $10.4M for a new zinc casting plant which included an electric induction furnace, new casting and slab handling equipment, and improved dust emission control.

3. PROBLEMS & POSSIBLE SOLUTIONS

3.1 Mining/Milling

A major problem facing HBMS is the declining proven ore reserves and the uncertain supply of custom concentrates in the Flin Flon area. It is imperative that an adequate exploration program be implemented to at least maintain historical levels of provem ore reserves, and in this manner provide the justification necessary for modernization of the smelter complex. In addition there is an incentive to improve mill recoveries, particularly zinc, gold and silver, and to improve zinc/copper separation. The production of lower grade concentrates to achieve higher metal recoveries can also be considered provided a modernized integrated extraction/refining process is also developed capable of obtaining very high overall recovery of valuable metals in the metallurgical treatment plant.

3.2 Copper Smelting/Refining

The copper smelter as a whole is labour intensive and overall operating costs are high compared to modern flash or continuous copper smelters which use oxygen to minimize carbonaceous fuel requirements. Fuel consumption in the roasters and reverberatory furnace is high because the process does not make efficient use of the sulfur fuel in the concentrate to minimize energy requirements. In addition the SO_2 content of off-gases from the roaster, smelter and converter operations is either too low and/or

too variable for efficient capture and fixation as sulfuric acid. Even if acid could be produced, the long transportation distances to market could result in negative netbacks to the smelter of up to $45/tonne H_2SO_4.

The slag fuming plant is also a high cost, high energy consuming operation. Although zinc recovery is reported at 85%, total zinc recovery from the copper plant is only about 60% of this figure because of the need for a bleed stream to control the build-up of impurities in the zinc fume and smelter dusts recycled to the zinc plant. This, coupled with the costs associated with drying, roasting and smelting the zinc plant residues in the copper plant prior to slag fuming make the total costs for this incremental zinc recovery very high. Costs however are partly off-set by the gold and silver recovered from the zinc plant leach residues, and from the recovery of waste heat in the form of steam from waste heat boilers located in the reverb and fuming furnace off-gas lines.

There is little that can be done economically with the existing copper plant to significantly increase productivity and energy efficiency, while facilitating SO_2 capture. Installation of a modern smelting facility (Inco or Outokumpu flash smelter, Noranda reactor or Mitsubishi continuous process), to replace the roaster/reverb operation would significantly reduce energy consumption and operating costs, and facilitate the capture of 50 to 100% of the SO_2 in a conventional acid plant. However, the problem of marketing sulfuric acid from a remote location would still remain. Ideally what is required is a process which can efficiently recover copper, zinc and precious metals while converting sulfides directly to elemental sulfur in the extraction step. Based on a recent assessment of alternatives (1, 2), a "chloride based" hydrometallurgical extraction process appears to offer the greatest potential for the development of a technically and economically viable process for the treatment of HBMS copper concentrates.

3.3 Zinc Extraction/Refining

The existing zinc plant suffers from essentially the same SO_2 emission control problems as the copper smelter. SO_2 concentrations in the roaster off-gases are too dilute for efficient capture in an acid plant and even if capture fixation as sulfuric acid was feasible, the marketing of acid from a Flin Flon location would be prohibitively expensive. The operating costs of the zinc plant are also relatively high and zinc recovery, even including that recovered in the zinc fuming plant, is only about 83%.

Installation of fluid bed roasters to replace the existing multi-hearths would reduce operating costs and produce a high concentration (appr. 10%) SO_2 gas readily amenable to capture in an acid plant. However, as with the copper pyrometallurgical alternatives, the sulfuric acid marketing problem still remains. Zinc recovery would also remain low, unless a strong acid leach circuit, with a jarosite or equivalent process for iron removal, was also installed.

As with copper, what is ideally required is a process which efficiently recovers zinc, copper and precious metals while converting sulfides directly to elemental sulfur in the extraction step. For short to medium term application there is little doubt that the best approach for zinc plant modernization at HBMS would be the installation of the Sherritt "zinc pressure leach" process, which has already been successfully implemented on a commercial scale. The process produces elemental sulfur directly in the leach and has no SO_2 emission problems. In addition zinc recovery from the zinc concentrate would be at least 98%, and capital costs would be substantially lower than a conventional roast leach plant, primarily because an acid plant would not be required.

4. PROPOSED PROCESSING ALTERNATIVES AND MODERNIZATION OPTIONS

The following processing alternatives are deemed to be the most practical for short to medium term implentation, while maintaining a reasonable compromise between maximizing environmental benefit and productivity, and minimizing cost and technological risk. "Processing alternatives" are specific to milling, to copper processing, and to zinc processing. It is convenient to comment on these separately from what may be termed the "Modernization options" which are simply combinations of "Processing alternatives" selected for this study.

4.1 Milling Alternatives

Although improvements in milling offer the greatest potential for increases in metal recovery, particularly of precious metals, an evaluation of mill processing alternatives was not included in the present study. Consequently the copper and zinc modernization options outlined here, assume that milling practices remain the same as in present operations (base case).

4.2 Copper Extraction/Refining Alternatives

Two processing alternatives were selected for evaluation. The Inco flash smelting process (3) was selected as the best pyrometallurgical alternative, based on an HBMS study (4) which maximized the use of existing auxilliary equipment. A conceptual flowsheet is shown in Figure 2. The process efficiently utilizes oxygen to minimize fuel requirements, and provides the flexibility to produce liquid SO_2 or sulfuric acid from the flash furnace off-gases. However only about 50% of total SO_2 emissions can be efficiently captured (converter gases would be emitted to atmosphere) and the problem of marketing the sulfur by-product (SO_2 or H_2SO_4) would still remain.

This is a relatively short term alternative since no pre-development work would be required to implement the Inco technology.

Based on recent development work carried out in Canada, the Great Central Mines (GCM) "Hydrometallurgical Copper Process" (2) was selected as the most promising hydrometallurgical extraction alternative for application at HBMS. A conceptual flowsheet is shown in Figure 3. The process can obtain high recoveries of copper and silver from either high or low grade copper concentrates, and produces an easily disposable or recoverable elemental sulfur by-product directly in the leach. Since no SO_2 is produced, there are no production constraints related to SO_2 emissions or marketing of sulfur by-products. The process can be economically viable at relatively low throughputs and has the potential to produce high purity copper directly, without further refining. However the process requires further development work over a two to four year period to verify its technical and economic viability for application to HBMS copper concentrates. Particular emphasis will be required on technological aspects related to gold and zinc recovery and the production of high purity copper.

4.3 Zinc Extraction/Refining Alternatives

The "Zinc Pressure Leach" (ZPL) process (5), developed by sherritt Gordon Mines Ltd., and successfully installed and operated by Cominco at Trail, B.C. and Kidd Creek at Timmins, Ont., was the only process selected for evaluation. A conceptual flowsheet is shown in Figure 4. The process fixes sulfur in the elemental form directly in the leach, and has already been operated on a commercial scale (integrated with a conventional zinc plant), and shown to be an economically attractive alternative. For HBMS however, some further development work will be required to determine optimum conditions for a two-stage leach, and to verify that the process can operate on a "stand alone" basis, without concern for build up of halide impurities. A two-stage leach is desirable at HBMS to minimize acid consumption and iron removal costs in the process.

4.4 Modernization Option #1

This is a relatively short term option in which the present Zinc roast leach plant would be replaced by a two-stage Zinc pressure leach process.

The ZPL would be installed in the present zinc oxide fume leach area. The existing fume leaching capacity would therefore be lost during construction.

The existing zinc plant purification, cadmium recovery, electrowinning and casting facilities would continue to be used. The ZPL residues, after sulfur separation would continue to be processed in the existing copper smelter. The zinc fuming furnace would also continue to operate, along with the dehalogenation roaster. However the zinc oxide fume would be fed directly to the ZPL process and the fume leach circuit would not be required. Stockpiled zinc-bearing residues would continue to be processed through the copper smelter. This alternative would result in higher zinc recoveries, lower operating costs and a reduction in SO_2 emissions of about 26%.

4.5 Modernization Option #2

This would be an add-on to Option 1, and would be a short to medium term alternative in which the existing copper reverberatory furnace would be replaced by an Inco-flash furnace.

The flash furnace would be installed to one sie of the existing reverberatory furnace with little disruption to copper output during construction. The existing converters, anode furnace, casting plant and feed preparation plant would continue to operate. The new facility would include oxygen and acid plants, and necessary modifications to existing materials handling, drying, converting and gas cleaning facilities.

Stockpiled residues would continue to be processed. Zinc plant residues , after sulfur removal, would be fed to the flash smelter, and as in alternative #1, the zinc fuming furnace and dehalogenation roaster would continue to operate, with zinc fume being recycled directly to the ZPL process.

This alternative would result in lower operating costs in both zinc and copper plants and a total reduction in SO_2 emissions of about 61%. The latter would be split between capture as potentially saleable sulfur from the ZPL process residues (26%), and capture as sulfuric acid from the Inco flash furnace gases (35%).

4.6 Modernization Option #3

This would also be an add-on to Option 1, and would be a medium to long term substitute for Option 2. The existing copper smelter would essentially be replaced with the GCM hydrometallurgical copper process. The new plant would require a separate location within the present HBMS site. During construction the copper smelter would continue to operate, without any disruption to copper output. The new plant might be able to utilize some of the existing equipment (materials handling, utilities, melting and casting etc.), if this can be accomplished withough seriously disrupting copper production during the change-over and if melting and casting of the copper product from the new process is required for marketing.

Zinc in the copper concentrate would also be recovered hydrometallurgically and recycled in an acceptable form to the ZPL process. It is also assumed that stockpiled zinc bearing residues would continue to be processed by feeding directly to the ZPL process. Since extraction of zinc in both the GCM and ZPL processes would be very high, operation of the zinc fuming furnace and oxide leach circuit would not be necessary. However, the dehalogenation roaster might still be required, if chloride levels in the zinc product from the GCM process are too high.

This alternative would result in higher zinc and copper recoveries and lower operating costs in both zinc and copper plants. SO_2 emissions would be completely eliminated. In addition most of the sulfur associated with the zinc and copper minerals could be recovered as a saleable product if economics so warrant. However an acceptable method will have to be developed for recovering gold and residual silver values from the GCM and ZPL process leach residues, as the loss of these precious metal values would be completely unacceptable to HBMS.

5. METHODOLOGY FOR COMPARISON OF MODERNIZATON OPTIONS

To evaluate the impacts of modernization the three modernization Options are compared to the present operations (base case).

Composite ore and concentrate analyses, recoveries and throughputs and subsequent smelter metallurgical balances for the base case are calculated from the following internal HBMS memos and reports, and from discussions with HBMS personnel.

1) HBMS 1983 Long Range Plan Mine Schedule;
2) HBMS Metallurgical Balance for 1982;
3) HBMS Report on Plant modernization (Ross/Wittleton December, 1982);
4) HBMS Preliminary Flowsheet (Wittleton February, 1983)
5) HBMS Smelter Flowsheet;

Custom ore and concentrate analyses and recoveries are estimated from representative data obtained from EMR (MPS) Mine/Mill Monitoring Programs.

Metallurgical balances and costs for the modernization alternatives are based primarily on information obtained from HBMS, CANMET, Inco and Consultants' reports. (1, 2, 3, 4, 6, 7, 8, 9, 10).

All mass balances are based on a copper output (as anodes) of 72,000 sty (65,318 mty) and a zinc output of 76,000 sty (68,948 mty) as ingots.

Material quantities are expressed in metric tons, pounds, and troy ounces per year. Analyses are expressed as percentages or troy ounces per metric ton.

5.1 Feed Sources

Although the HBMS ten year forecast (1983-1992) shows an increasing dependancy on purchased concentrates, this

comparative study is based on equal supplies of copper in concentrates from HBMS and Custom sources respectively.

This 1:1 split is also applied to zinc in concentrates for the base case. However, for the modernization alternatives, higher zinc recoveries will allow lower inputs of zinc concentrates. It is assumed that this reduction in zinc input will result from smaller purchases of custom zinc concentrates.

Stockpiled zinc plant leach residues are included as an HBMS source of zinc. Inputs are assumed to be constant at 6,530 mty for all options. For the base case and modernization options 1 & 2, these residues are added to the copper smelter feed, because zinc is recovered in the slag fuming furnace in these cases. For Options 3 however, it is assumed that zinc residues will be added to the ZPL process feed, because the fuming furnace will not be operating, and because it is desirable to minimize the zinc content of the feed to the hydrometallurgical copper process.

5.2 Mill Throughputs & Recoveries

Mill throughputs, grades and recoveries for the base case, options 1&2 and option 3 are shown in Tables 1, 2 & 3 respectively. Ore and concentrate grades and recoveries are common to all three tables, since it is assumed that milling practices are the same for all options. The estimated custom ore inputs and recoveries are shown, but are not really relevant since HBMS purchases only concentrates. Milling recoveries are independent of the copper and zinc extraction plants and appear unchanged on subsequent tables 4, 5, 6&7.

It should be noted that total throughputs, particularly of zinc, will not necessarily correspond to mill recoveries from ore, because stockpiled leach residues make up a portion of the total plant feed, and custom ore requirements are based on copper throughputs only.

Total throughputs are of course dependent upon subsequent recoveries of copper and zinc in the smelting/refining processes. The reduction in purchased zinc concentrate requirements for the modernization options (mentioned in the previous section), is quantified in Tables 2 & 3. Options 1 & 2 require a custom zinc concentrate output about 12,600 mty (17.6%) less than the base case, while option 3 requires about 21,360 mty (29.7%) less than the base case.

A very small reduction in custom copper concentrate requirements of about 2,700 mty (2%) is also noted in option 3, because of the slightly higher copper recovery achieved in the hydrometallurgical extraction process.

5.3 Smelter Throughputs & Recoveries

Copper and zinc smelter metallurgical balances, for the base case and modernization options are shown in Tables 4, 5, 6 & 7. The figures are based in the following assumptions:

5.3.1 For Base Case & Modernization Options 1 & 2

1) To simplify the metallurgical balances, internal recycle streams are not shown. Thus the copper smelter feed does not include zinc plant residues and the zinc plant feed does not include ZnO fume, and zinc and precious metals are shown as outputs from both copper and zinc plants. In fact all precious metals are recovered in the copper smelter and all saleable zinc is produced in the zinc plant. The recovery figures for precious metals in zinc concentrate, and zinc in copper concentrate are based on HBMS estimates.

2) Overall recoveries of copper, silver and gold in modernization options 1 & 2 remain the same as the base case, namely 95.5% for Cu, 96.0% for Ag & 94.5% for Au. Overall copper recovery is based on 95.8% recovery in the copper smelter and 73.5% recovery in the zinc plant.

3) Overall zinc recovery in options 1 & 2 increases by 7% over the base case (90.4% vs 83.4%). This figure is based on obtaining 99% zinc extraction in the ZPL process and 98% recovery in the zinc plant. Zinc recovery from copper concentrate in the copper plant is assumed to be 37.6%

4) The higher zinc recovery in options 1 & 2 results in an 8.7% reduction in total zinc concentrate requirements. This also results in a very small increase (0.1%) in copper concentrate requirements (to maintain constant Cu output) and very small decreases in total silver and gold outputs of about 1.5% and 0.2% respectively, compared to the base case.

5) For the base case and options 1 & 2 all zinc plant leach residues are recycled to the copper smelter, and all sulfur entering the smelter complex is shown leaving as either elemental sulfur, sulfuric acid or SO_2 emissions. In fact actual SO_2 emissions will be 2 to 3% less than those shown, because of sulfur in discard slags, (all options) and neutralized weak acid from acid plant scrubbers (option 2 only).

6) For option 2, sulfuric acid production is based on 50% sulfur removal as SO_2 in the flash furnace, and 96% capture of this SO_2 in the acid plant.

7) Recoverable sulfur from the ZPL process is based on 98% conversion of sulfides (except pyrite) to elemental sulfur, and an assumed loss, during hot filtration of the sulfur product, equivalent to 30% of the weight of sulfide residue (pyrite plus residual sulfides). Overall sulfide conversion to elemental sulphur is calculated to be 83.5% of total sulfur input. Total sulfide content of the leach residue is 15% of input sulfur, based on an average pyrite content of 8% in the zinc concentrate. Jarosite sulfur is assumed to be equivalent to 1.5% of total input sulfur, based on oxidation of about 10% of the pyrite sulfur to sulfate.

8) Total recoverable elemental sulfur in the ZPL process is about 75% of input sulfur for all three modernization options.

5.3.2 **For Modernization Option 3**

1) Recovery of copper in the GCM process is assumed to be 98%, based on 99% copper extraction in the leach. Recovery of copper from zinc concentrate is assumed to be constant at 73.5% for all zinc plant processing options. Overall recovery of copper for option 3 is therefore about 2% higher than the base case and other modernization options (97.7% vs 95.6%).

2) Recovery of zinc from copper concentrates in the GCM process is assumed to be 90% as zinc oxide which can be recycled to the zinc plant. This brings overall zinc recovery in option 3 to 97.1%, versus 90.4% in options 1 & 2 and 83.4% in the base case.

3) The higher recoveries of copper and zinc result in lower throughputs of copper and zinc concentrates, and consequently lower throughputs of gold and silver. Copper and zinc concentrate inputs are about 98.0% and 84.3% respectively of base case figures. Total gold and silver inputs are 2.4% and 4.7% respectively lower than base case inputs.

4) Recovery of gold and silver in option 3 is assumed to be about 5% lower than the other alternatives, because recovery of precious metals from leach residues will be more difficult and less efficient without a copper smelter. Overall outputs of gold and silver are therefore about 7.8% and 9.8% respectively lower than base case outputs and 7.6% and 8.4% lower than options 1 & 2.

5) In option 3 there are no SO_2 emissions. All sulfur entering the copper and zinc plants is either recovered as elemental sulfur or rejected in leach residues as pyrite, other unleached sulfides and/or jarosite.

6) For the zinc plant, overall conversion of sulfide to elemental sulfur is slightly lower (83.0 vs 83.5%), and jarosite sulfur is slightly higher (2.0 vs 1.5%) than for options 1 & 2. This is because the stockpiled residue which contains sulfur primarily as sulfate (65% of input sulfur), is fed to the zinc plant instead of the copper plant. However, recoverable sulfur, although somewhat lower (at 27,340 mty) than options 1 & 2 because of the lower throughput of zinc concentrate, remains at about 75% of input sulfur.

7) For the GCM copper process, recoverable sulfur is based on the same criteria for sulfide conversion and elemental sulfur recovery as that used in the ZPL process (Item 7 in section 5.3.1). However the sulfide content of leach residue is 19.8% of input sulfur, based on an average pyrite content of 10% in the copper concentrate. Overall sulfide conversion to elemental sulfur is therefore only 81.4% of input sulfur, and recoverable sulfur is reduced to 70.7% (58,960 mty). Total recoverable sulfur in option 3 is 86,300 mty, or 72% of total input sulfur.

8) It is also assumed that sulfide oxidation to sulfate is negligible in the GCM process, and that jarosite is not formed during the leach. If some sulfate is produced due to pyrite oxidation it can be removed as Jarosite or gypsum, and if anything will have a beneficial effect on elemental sulfur recovery, since less pyrite will result in a lower entrained sulfur loss after hot filtration.

5.4 Capital Costs

A breakdown of Capital cost estimates for the processing alternatives is shown in Table 8. The estimates are based primarily on CANMET (1, 2) HBMS (4, 6), Inco (3), SNC (8), and consultants (7) reports, and on CANMET in-house data. For the ZPL process it is assumed that the existing purification, cadmium recovery, electrowinning and casting facilities can be used, and that building costs are confined to modifications of existing structures and equipment. For

the Inco flash smelter, items excluded from the capital costs include converters, anode furnace, casting facilities and feed preparation plant. As with the ZPL process, building costs are confined to modifications requred.

For the GCM copper process capital costs are essentially equivalent to a new greenfields plant. Costs for the "extraction" plant include iron removal and disposal, and estimates of additional costs associated with zinc recovery. Engineering and contractor's fees are included in all cost estimates, along with a contingency allowance of 15% for the ZPL and Inco flash smelting processes, and 30% for the GCM process. The higher contingency for the latter reflects the greater degree of uncertainty in the technology.

All capital costs have been up-dated to December 1983 dollars. However, since detailed engineering has not been carried out, cost estimates can only be considered accurate to $\pm$ 30%

5.5 Operating Costs

A breakdown of incremental operating costs for the modernization options is shown in Table 9. Base Case costs are from HBMS data (6), and from discussions with HBMS personnel. Modernization costs are based primariy on the same referenced reports used to derive capital costs, and on CANMET in-house data. For acid plant costs (both capital and operating) additional data from previous CANMET studies (9, 10) were also used. Copper refining costs and incremental mining, milling and custom concentrate costs were provided by HBMS.

Fuming plant costs have been apportioned between copper and zinc plants in the ratio of zinc in their respective concentrate feeds.

In the cost breakdowns shown the term "other" refers primarily to operating and maintenance materials and supplies. Costs do not include corporate overhead, interest

For option 1 the decrease in annual operating costs ($7.46 million) is due to decreased mining/milling costs (lower custom concentrate requirements resulting from higher zinc recovery) and to lower zinc plant operating costs. For option 2 these same reductions apply, but in addition copper plant operating costs are reduced by about $10.9 million, because savings in copper smelting (flash furnace versus reverb) and elimination of the copper roasters more than off-sets acid plant operating costs.

For option 3 additional savings are realized due to a further reduction in concentrate requirements, and elimination of drying, slag fuming, copper refining and acid plant costs.

5.6 Products and Revenues

A breakdown of products and revenues for the base case and modernization options is shown in Table 10. Copper and zinc outputs are constant in all cases, as defined in the methodology. Gold and silver outputs in the modernization options reflect the reduction in concentrate inputs in all three options, and the reduction in gold/silver recovery from the leach residues in option 3. Lead concentrate output is dependent on input of HBMS concentrates only, and is therefore essentially constant for all cases. Production of sulfur and sulfuric acid is based on the recoveries documented in Tables 4 to 7.

Revenues are based on EMR and DRIE commodity forecasts for metal and acid prices in the 1990's. All prices are in 1983 dollars. Prices used reflect a 5% deduction for refining charges for recovery of precious metals from copper anodes, and a 10% refining charge for recovery from residues.

Netbacks to the smelter for sulfuric acid are based on best and worst case scenarios for shipping to a Chicago

6. IMPACTS OF MODERNIZATION

The impacts of modernization are summarized in Table 11, which shows incremental outputs, revenues and operating costs for each modernization option, along with total capital costs and SO_2 emissions. All incremental figures are relative to the base case. The reduction in precious metals (PM) revenues for options 1 & 2 (1.5% for Ag; 0.2% for Au) is due entirely to decreased zinc concentrate input resulting from higher zinc recovery. The reduction in PM revenues for option three (14.3% for Ag; 12.4% for Au) is due to decreased copper and zinc concentrate input, decreased recovery (5%) and decreased product value (5%). The latter reflects the added costs of recovering gold and silver from the ZPL and GCM process leach residues. For silver about 33% of the reduced revenue is attributable to lower concentrate input, about 35% to reduced recovery and the remainder (32%) to reduced value. For gold the revenue reduction is about 19% attributable to lower concentrate input, about 44% to reduced recovery and about 37% to reduced value.

For options 1 & 2 sulfur revenues can more than compensate for the loss in PM revenues. However for option 2, the negative netbacks from sufuric acid sales will essentially eliminate any potential increase in annual revenues, and could result in a reduction in revenues of over $5.5 million/year.

For option 3 the reduction in revenues due to PM losses is estimated to be at least $7 million/year even after credits for sulfur are considered. Nevertheless total annual operating surplus for option 3 is nearly $43 million/year, because of the large savings in operating costs of $50 million/year.

All of the modernization options result in substantial savings in operating costs. For option 1, savings of about $7.5 million/year are attributable to reduced mining/milling (custom concentrate) costs (61%) and reduced zinc extraction costs (39%). For option 2, savings of about $18 million/year are distributed between mining/milling (25%), zinc plant (16%) and copper plant (59%). For option 3

savings of about $50 million/year are distributed between mining/milling (20.5%), zinc plant (25%) and copper plant (54.5%). Elimination of copper refining costs accounts for 37% of the total $50 million/year savings, while zinc fuming plant costs account for 22%.

Capital costs for the three options are $C43 million for option 1, $C170 million for option 2 and $C173 million for option 3.

In summary all three modernization alternatives generate a significant annual operating surplus, because of reduced operating costs. Based on the capital cost estimates shown, option 1 would have a capital cost payback (neglecting interest charges) of about 5.3 years while the payback for option 3 would be about 4 years. For option 2, payback would be betwen 9 and 13 years depending on sulfuric acid netbacks.

The effect on SO_2 emissions would be most dramatic for option 3, where a 100% reduction would be achieved. For options 2 & 1 reductions would be about 61% & 26% respectively.

7. EVALUATION OF MODERNIZATION OPTIONS

7.1 Option 1

There is little doubt that the zinc pressure leach (ZPL) process is the best short to medium term alternative for modernization of the HBMS zinc plant. The process would substantially reduce ore and concentrate requirements due to higher zinc recovery, and significantly reduce zinc plant operating costs. The development work required to verify the applicability of the process to HBMS zinc concentrates has already been initiated by sherritt Gordon under contract with HBMS, and with financial assistance from the Department of Regional Industrial Expansion (DRIE). If the results of this testwork confirm the capital and operating cost estimates, and if a long term supply of concentrates can be assured, there is a reasonable chance that HBMS can justify proceeding with the zinc plant modernization, based on a capital payback of about 5 years. It is possible however,

that operation of the zinc fuming plant to recovery the zinc in the copper smelter feed (Cu concentrate, stockpiled residues and ZPL residues) would no longer be economic, because the ZPL residues would contain so little zinc and stockpiled residues can be fed to the ZPL process. In this case, overall zinc recovery for option 1 would decrease from 90.4% to 85.8%, or only about 2% higher than base case zinc recovery. This points out the importance of improving milling/beneficiation practices to reduce the zinc content of the copper concentrate and maximize overall zinc recovery without having to operate the high cost zinc fuming plant.

7.2 Option 2

The Inco flash smelter is probably the lowest cost short term alternative for modernization of the HBMS copper plant, and would require no pre-development for implementation. Operating costs in the copper smelter would be substantially reduced. Other pyrometallurgical processes (Outokumpu, Noranda, Mitsubishi) would be more efficient in terms of SO_2 capture, but their capital and operating costs would be significantly higher because of slag cleaning requirements, reduced oxygen utilization and higher gas cleaning and SO_2 capture costs.

As with option 1, zinc recovery from the copper concentrate would still require operation of the high cost zinc fuming plant. In addition the negative netbacks from sulfuric acid would result in decreased revenues to the smelter. The more acid produced the greater the revenue loss. This constraint makes all the pyrometallurgical copper processes look unattractive for a Flin Flon location.

The capital payback period for option 2, is dependent on the acid netback, but on average would be at least 10 years, or double that requied for option 1. If the Inco flash smelter alone was installed, without the ZPL process, operating cost savings would be reduced to $10.85 from $18.3 million/year, and total operating surplus, depending on acid netbacks, would be in the range $4.55 million to $10.15 million per year. Capital payback for the new copper

smelter would therefore require 12 to 28 years. This would not appear to be an attractive alternate for modernization of the HBMS copper smelter.

7.3 Option 3

The GCM hydrometallurgical copper process is a medium to long term alternative for HBMS copper plant modernization, requiring extensive development work to verify the technical and economic viability of the process. Based on the capital and operating costs documented it appears to be an attractive alternative for HBMS at Flin Flon.

Integrating the GCM and ZPL processes could provide an option which removes all SO_2 and sulfuric acid marketing constraints, and at the same time could produce a saleable sulfur by-product, which could be sold at a positive netback to the plant, or stockpiled if sulfur prices are depressed.

The capital payback period for option 3 could be as low as 4 years, if the capital and operating cost estimates prove to be valid. Evaluation of the GCM process alone (without the ZPL) would indicate an operating cost savings of about $42.7 million/year and a net operating surplus of $34.7 million/year. This would result in a capital payback period of about 3.7 years. The major factor affecting this economic analysis is the value of the copper product. If a high purity copper product, equivalent to electrorefined copper, cannot be produced, the capital payback period required could more than double.

Other factors which will have a very significant effect on the viability of option 3 are the recovery of precious metals from GCM and ZPL process residues, and the recovery of zinc from copper concentrates in the GCM process. If the latter proves successful it will ensure high overall zinc recoveries in the integrated plant regardless of the zinc distribution between zinc and copper concentrates. The importance of precious metals recovery to HBMS cannot be over emphasized, since in the present operations PM revenues account for at least 25% of total revenues.

Technology development initiatives therefore will have to find acceptable solutions to all three problem areas noted here, before option 3 can become a truly attractive alternative for HBMS.

8. RECOMMENDED TECHNOLOGY DEVELOPMENT INITIATIVES

8.1 Mining/Milling

Mining and Milling costs, and the cost of custom concentrates, constitute a very high percentage (≈65%) of total HBMS operating costs. It is very important therefore, for the future viability of the Flin Flon operation, to not only ensure an adequate supply of proven ore reserves, but also to enhance economic recovery from these reserves by developing lower cost mining methods, and improved milling methods which will increase recovery of metal values from the ore. Present average mill recoveries of gold and silver are about 64% and 74% respectively, while average zinc recovery is about 86%. There is an incentive therefore to improve these recoveries, and also to improve zinc/copper separation during the production of selective concentrates. To accomplish this a comprehensive R&D program to develop improved mineral beneficiation techniques, based on the mineralogical properties of the various ore bodies, is required.

8.2 Smelting/Refining

For the zinc plant modernization, confirmation of optimum conditions, operating costs and enigneering design for the two-stage ZPL process is required. As stated previously, this testwork has already been initiated, and data adequate to carry out detailed engineering design and costing studies should be available very soon. Some further development work may be desirable to better define optimum conditions to maximize zinc and copper extraction, and minimize problems related to the control of iron, sulfate and chloride, and the recovery of sulfur and precious metals from the ZPL residues.

For the copper plant modernization, bench scale tests will be required to determine the applicability of the GCM

process to HBMS copper concentrates, and to optimize conditions for the extraction and recovery of copper, silver, zinc and sulfur. The feasibility of producing a high purity copper product will have to be determined, and cost effective methods for recovering precious metals from the process leach residues will have to be developed. Finally pilot scale development work will be required to obtain engineering design and cost data and confirm the technical and economic viability of the process.

9. ACKNOWLEDGEMENTS:

The assistance of HBMS personnel and Mr. F. Swinkels, consultant, in providing the data necessary for generating the costs and material flows documented in this report, is gratefully acknowledged.

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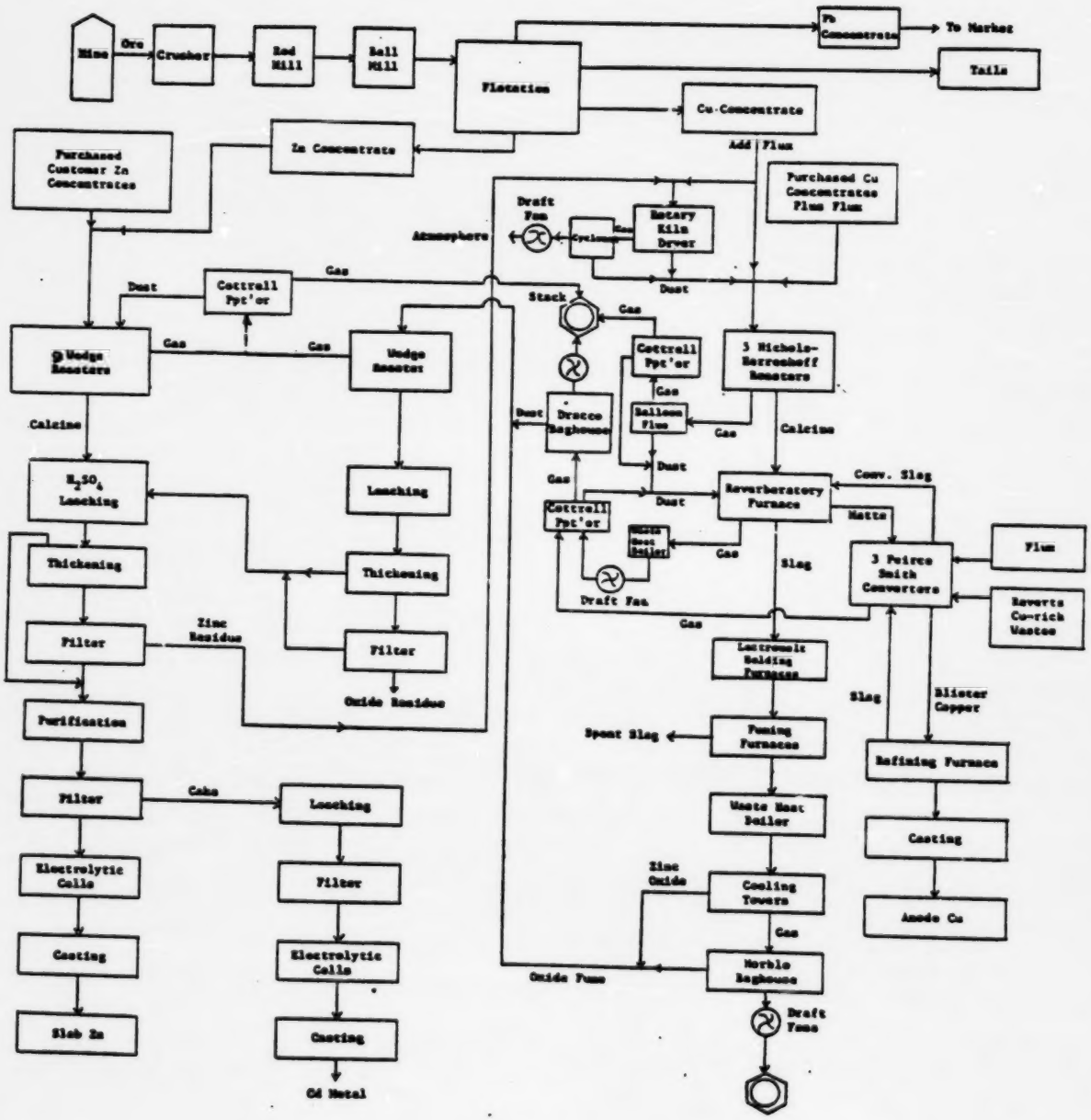
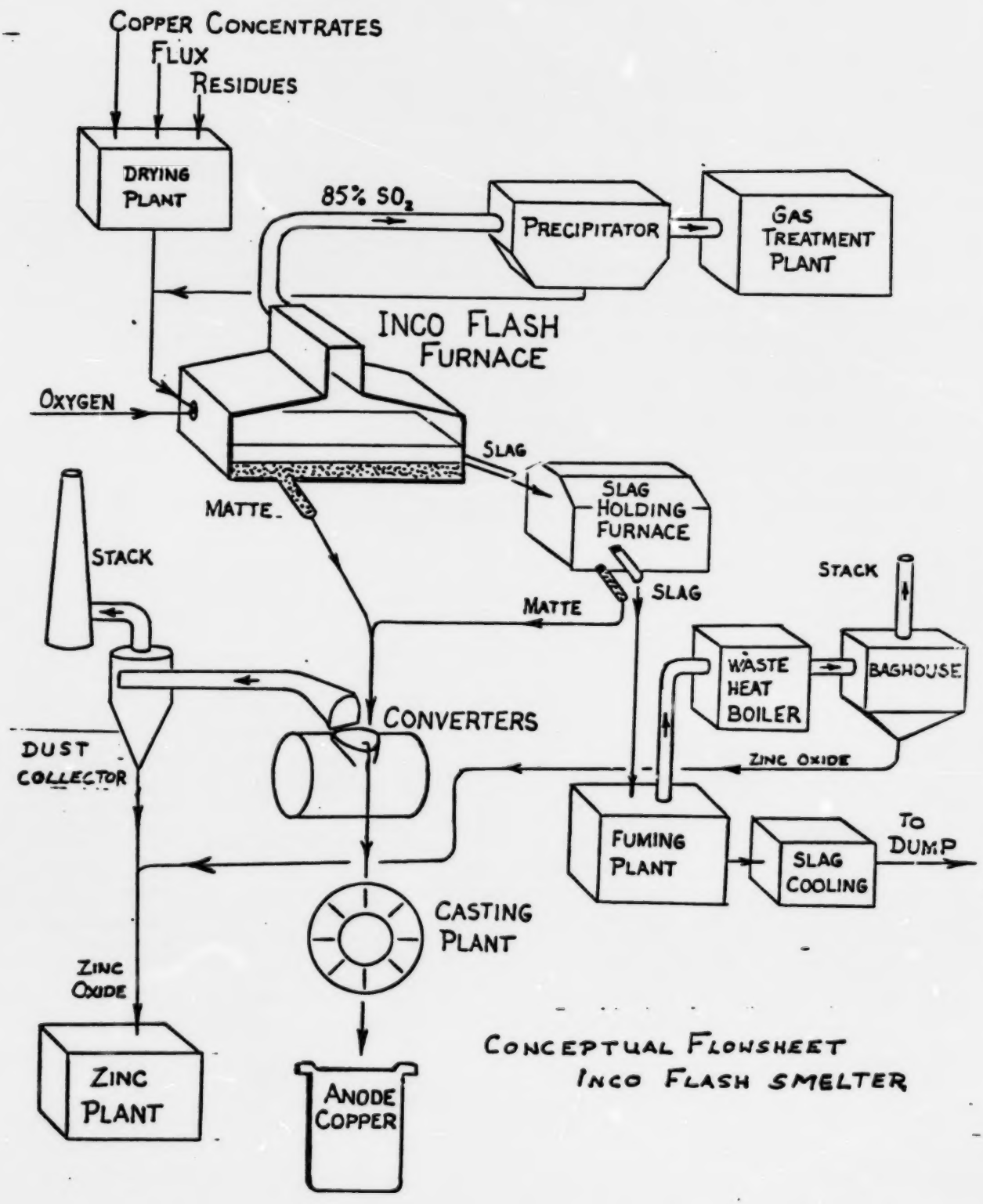
FIGURE 1

HBMS





CONCEPTUAL FLOWSHEET
INCO FLASH SMELTER

FIGURE 3

GREAT CENTRAL MINES

HYDROMETALLURGICAL COPPER PROCESS

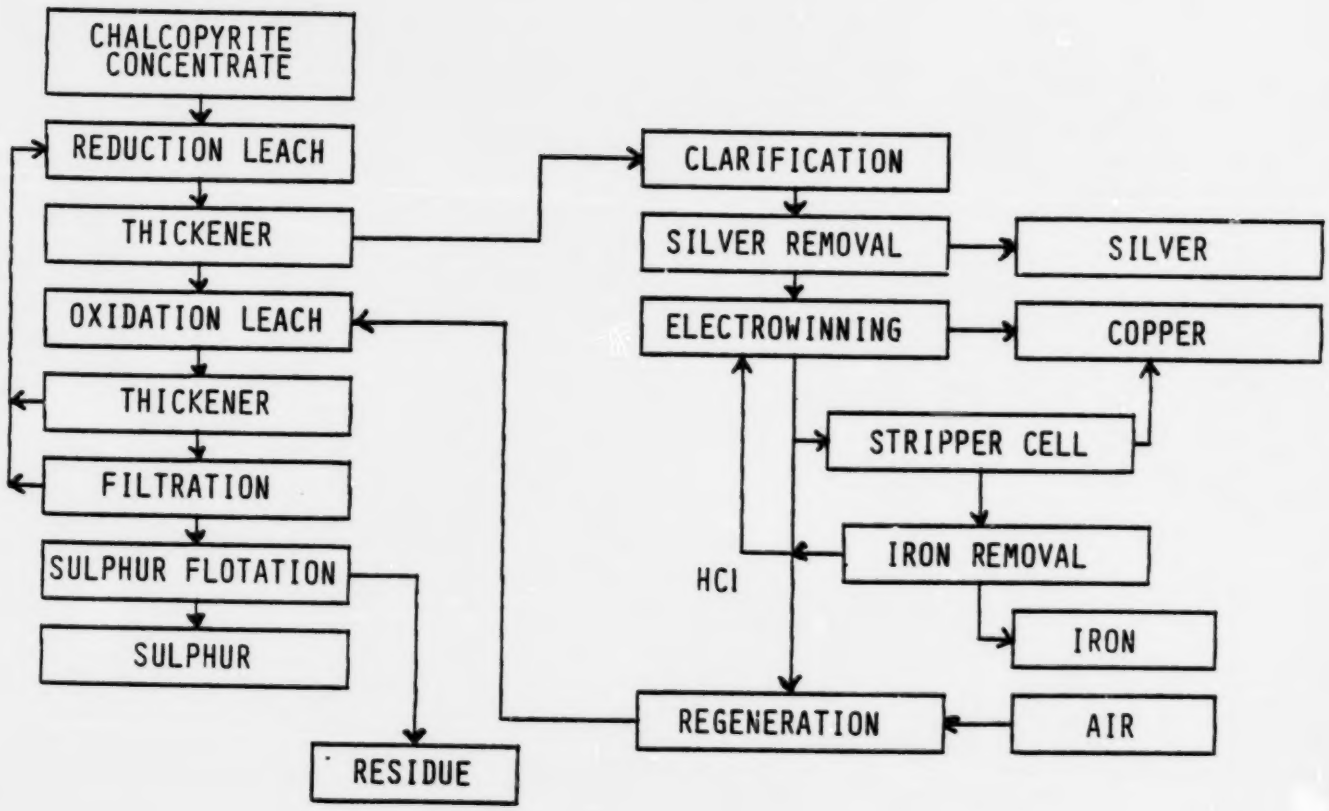


FIGURE 4

SHERRITT ZINC PRESSURE LEACH PROCESS

GRASS ROOTS PLANT

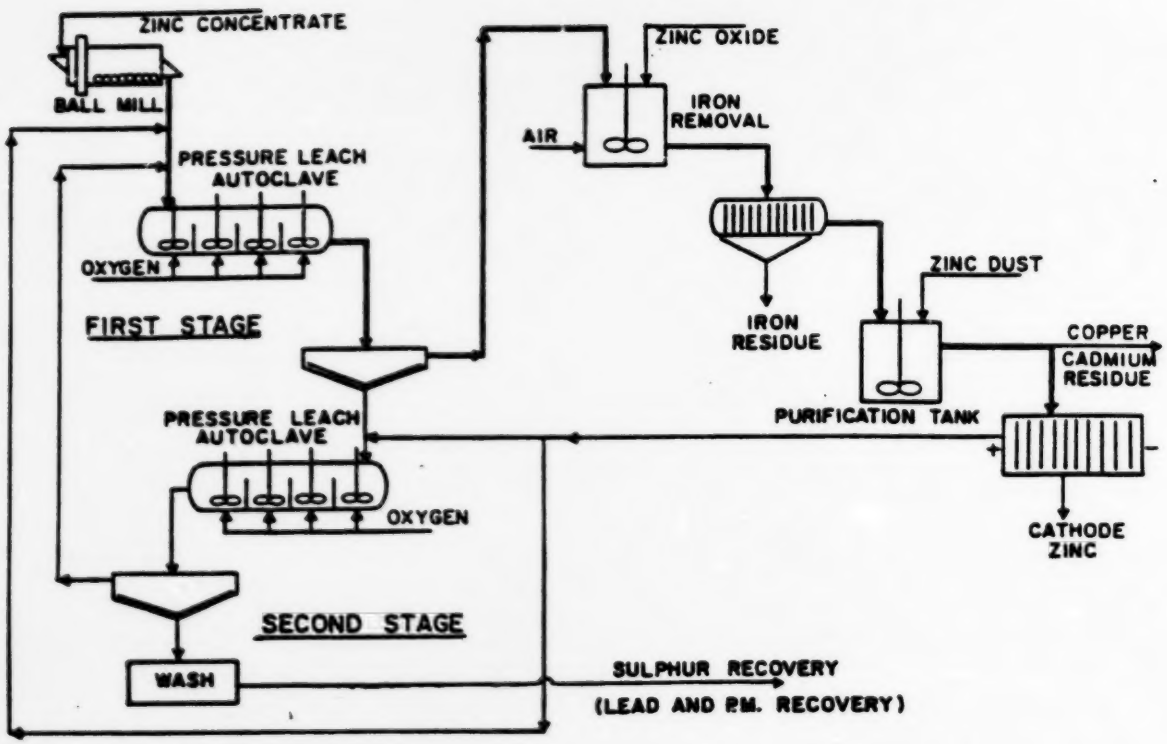


TABLE 1 HBMS
Base Case

MILL THROUGHPUTS, GRADES, AND RECOVERIES
(Including Stockpiled Leach Residue)

ORE AND CONCENTRATE THROUGHPUTS			METAL THROUGHPUTS (10^3 mty or 10^3 oz/y)						METAL GRADES (% or oz/mt)						MILL RECOVERIES (%)					
Source	Type	10^3 mty	Cu	Zn	S	Ag	Au	Pb	Cu	Zn	S	Ag	Au	Pb	Cu	Zn	S	Ag	Au	Pb
HBMS	Ore	1,600	36.80	48.60		992	79.76	2.35	2.30	3.04		0.621	0.050	0.15						
Custom	Ore	2,083	37.08	45.20		1,361	63.49		1.78	2.17		0.654	0.031							
Total	Ore	3,683	73.88	93.80		2,353	143.25													
HBMS	Copper conc	168.33	33.67	5.39	47.0	552	39.52	0.63	20.0	3.20	27.9	3.28	0.235	0.38	91.5	11.1		55.6	49.6	27
HBMS	Stock.L. Res.	6.53	0.08	1.72	0.5	20	0.74		1.2	26.4	7.0	3.12	0.114		NA	NA		NA	NA	
HBMS	Total HB Cu	174.86	33.75	7.11	47.5	572	40.26													
Custom	Copper conc	127.33	33.74	2.42	38.1	908	45.59		26.5	1.9	29.9	7.13	0.358		91.0	5.4		66.7	71.8	
Total	Copper conc	302.19	67.49	9.53	85.6	1,480	85.85													
HBMS	Zinc conc	72.84	0.37	36.57	19.4	109	5.38	0.98	0.5	50.2	26.7	1.49	0.074	1.35	1.0	75.2		11.0	6.8	42
Custom	Zinc conc	71.98	0.50	36.56	24.0	171	1.86		0.7	50.8	33.4	2.37	0.026		1.4	81.0		12.5	2.9	
Total	Zinc conc	144.82	0.87	73.13	43.4	280	7.24													
HBMS	Cu + Zn conc	247.70	34.12	43.68	66.9	681	45.60								92.5	86.3		66.6	56.4	
Custom	Cu + Zn conc	199.31	34.24	38.98	62.1	1,079	47.44								92.4	86.4		79.3	74.7	
Total	Cu + Zn conc	447.01	68.36	82.66	129.0	1,760	93.04								92.5	86.3		73.9	64.4	
HBMS	Lead/Silver conc	0.48				18	0.17	0.27	1.1	4.4		38.0	0.35	56.6				1.8	0.2	11

TABLE 2 HBMS
Options 1 & 2

MILL THROUGHPUTS, GRADES, AND RECOVERIES
(Including Stockpiled Leach Residue)

ORE AND CONCENTRATE THROUGHPUTS			METAL THROUGHPUTS (10^3 mty or 10^3 oz/y)						METAL GRADES (% or oz/mt)						MILL RECOVERIES (%)					
Source	Type	10^3 mty	Cu	Zn	S	Ag	Au	Pb	Cu	Zn	S	Ag	Au	Pb	Cu	Zn	S	Ag	Au	Pb
HBMS	Ore	1,600	36.80	48.60		992	79.76	2.35	2.30	3.04		0.621	0.050	0.15						
Custom	Ore	2,086	37.13	45.28		1,363	63.60		1.78	2.17		0.654	0.0305							
Total	Ore	3,686	73.93	93.88		2,355	143.36													
HBMS	Copper Conc	168.33	33.67	5.39	47.0	552	39.52	0.63	20.0	3.20	27.9	3.28	0.235	0.38	91.5	11.1		55.6	49.6	27
HBMS	Stockpile Res.	6.53	0.08	1.72	0.5	20	0.74		1.2	26.4	7.0	3.12	0.114		NA	NA		NA	NA	
HBMS	Total HB Cu	174.86	33.75	7.11	47.5	572	40.26													
Custom	Copper Conc	127.60	33.81	2.42	38.2	910	45.68		26.5	1.9	29.9	7.13	0.358		91.0	5.4		66.7	71.8	
Total	Copper Conc	302.46	67.56	9.53	85.7	1,482	85.94													
HBMS	Zinc Conc	72.84	0.37	36.57	19.4	109	5.38	0.98	0.5	50.2	26.7	1.49	0.074	1.35	1.0	75.2		11.0	6.8	41
Custom	Zinc Conc	59.32	0.42	30.13	19.8	140	1.53		0.7	50.8	33.4	2.37	0.026		1.4	81.0		12.5	2.9	
Total	Zinc Conc	132.16	0.79	66.70	39.2	249	6.91													
HBMS	Cu + Zn Conc	247.70	34.12	43.68	66.9	681	45.64								92.5	86.3		66.6	56.4	
Custom	Cu + Zn Conc	186.92	34.23	32.55	58.0	1,051	47.21								92.4	86.4		79.3	74.7	
Total	Cu + Zn Conc	434.62	68.35	76.23	124.9	1,731	92.85								92.4	86.3		73.9	64.4	
HBMS	Lead/Silver Conc	0.48				18	0.17	0.27	1.1	4.4		38.0	0.35	56.6				1.8	0.2	11

TABLE 3 HBMS
Option 3

MILL THROUGHPUTS, GRADES, AND RECOVERIES
(Including Stockpiled Leach Residue)

ORE AND CONCENTRATE THROUGHPUTS			METAL THROUGHPUTS (10^3 mty or 10^3 oz/y)						METAL GRADES (% or oz/mt)						MILL RECOVERIES (%)					
Source	Type	10^3 mty	Cu	Zn	S	Ag	Au	Pb	Cu	Zn	S	Ag	Au	Pb	Cu	Zn	S	Ag	Au	Pb
HBMS	Ore	1,570	36.11	47.72		975	78.49	2.31						0.15						
Custom	Ore	2,040	36.30	44.25		1,334	61.17													
Total	Ore	3,610	72.41	91.97		2,309	139.66													
HBMS	Copper conc	165.15	33.03	5.28	46.1	542	38.81	0.63	20.0	3.2	27.9	3.28	0.235	0.38	91.5	11.1		55.6	49.6	27
Custom	Copper conc	124.64	33.03	2.37	37.3	889	44.62		26.5	1.9	29.9	7.13	0.358		91.0	5.4		66.7	71.8	
Total	Copper conc	289.79	66.06	7.65	83.4	1,431	83.43													
HBMS	Zinc conc	71.50	0.36	35.89	19.1	107	5.29	0.98	0.5	50.2	26.7	1.49	0.074	1.35	1.0	75.2		11.0	6.8	42
HBMS	Stockpile Res.	6.53	0.08	1.72	0.5	20	0.74		1.2	26.4	7.0	3.12	0.114		NA	NA		NA	NA	
HBMS	Total HB Zn	78.03	0.44	37.61	19.6	127	6.03													
Custom	Zinc conc	50.62	0.35	25.72	16.9	120	1.31		0.7	50.8	33.4	2.37	0.026		1.4	81.0		12.5	2.9	
Total	Zinc conc	128.65	0.79	63.33	36.5	247	7.34													
HBMS	Cu + Zn conc	243.18	33.47	42.89	65.7	669	44.84								92.5	86.3		66.6	56.3	
Custom	Cu + Zn conc	175.26	33.38	28.09	54.2	1,009	45.93								92.4	86.4		79.3	74.7	
Total	Cu + Zn conc	418.44	66.85	70.98	119.9	1,678	90.77								92.4	86.3		73.9	64.4	
HBMS	Lead/Silver conc	0.47				18	0.17	0.27	1.1	4.4		38.0	0.35	56.6				1.8	0.2	11

TABLE 4 HRMS SMELTER THROUGHPUTS, GRADES & RECOVERIES
Base Case (Copper Reverberatory Smelting + Zinc Roast Leach, Electrowin Process)

	SMELTER FEED		SMELTER OUTPUTS	RECOVERIES %		
	Inputs mty or oz/y	Grades % or oz/mt	mty or oz/y	Ore to Conc.	Conc. to Metal	Ore to Metal
Copper Plant						
Smelter Feed*	302,190					
Copper	67,490	22.3	64,670	91.2	95.8	87.4
Zinc	9,530	3.15	3,580	8.3	37.6	3.1
Silver	1,480,000	4.90	1,439,900	62.0	97.3	60.3
Gold	85,850	0.284	81,710	59.4	95.2	56.6
Sulfur	85,600	28.3	-	-	-	-
S in Residues	0		0			
as S^o			0			
as Pyrite			0			
as Jarosite			0			
H_2SO_4			0			
SO_2 Emissions			171,200		100.0	
Zinc Plant						
Concentrate Feed	144,820					
Copper	870	0.6	640	1.2	73.5	0.9
Zinc	73,130	50.5	65,370	78.0	89.4	69.7
Silver	279,500	1.93	246,820	11.9	88.3	10.5
Gold	7,240	0.05	6,210	5.1	85.7	4.4
Sulfur	43,400	30.0	-	-	-	-
S in Residues			0			
as S^o			0			
as Pyrite			0			
as Jarosite			0			
H_2SO_4			0			
SO_2 Emissions			86,800		100.0	
Cu + Zn Plants						
Total Feed	447,010					
Copper	68,360		65,320	92.4	95.5	88.2
Zinc	82,660		68,950	86.3	83.4	72.0
Silver	1,759,500		1,686,720	73.9	96.0	70.9
Gold	93,040		87,920	64.5	94.5	61.0
Sulfur	129,000		-	-	-	-
S in Residues			0			
as S^o			0			
as Pyrite			0			
as Jarosite			0			
H_2SO_4			0			
SO_2 Emissions			258,000		100.0	

* Includes stockpiled residue

TABLE 5 HRMS **SMELTER THROUGHPUTS, GRADES & RECOVERIES**
Option 1 (Copper Reverberatory Smelting + Zinc Pressure Leach, Electrowin Process)

	SMELTER FEED		SMELTER OUTPUTS	RECOVERIES %		
	Inputs mty or oz/y	Grades % or oz/mt	mty or oz/y	Ore to Conc.	Conc. to Metal	Ore to Metal
Copper Plant						
Smelter Feed*	302,460					
Copper	67,560	22.3	64,740	91.2	95.8	87.4
Zinc	9,530	3.15	3,580	8.3	37.6	3.1
Silver	1,481,920	4.90	1,441,760	62.0	97.3	60.3
Gold	85,940	0.284	81,800	59.4	95.2	56.6
Sulfur	85,700	28.3	-	-	-	-
S in Residues	9,700		-			
as S^o			0			
as Pyrite			0			
as Jarosite			0			
H_2SO_4			0			
SO_2 Emissions			190,800		100.0	
Zinc Plant						
Concentrate Feed	132,160					
Copper	790	0.6	580	1.2	73.5	0.9
Zinc	66,700	50.5	65,370	78.0	98.0	76.4
Silver	249,470	1.89	220,310	11.9	88.3	10.5
Gold	6,910	0.052	5,930	5.1	85.7	4.4
Sulfur	39,200	29.7	-	-	-	-
S in Residues						
as S^o			32,700		83.5	
as Pyrite & Sulfides			5,900		15.0	
as Jarosite			600		1.5	
H_2SO_4			0			
SO_2 Emissions			0			
Cu + Zn Plants						
Total Feed	434,620					
Copper	68,350		65,320	92.4	95.6	88.3
Zinc	76,230		68,950	86.3	90.4	78.0
Silver	1,731,390		1,662,070	73.9	96.0	70.9
Gold	92,850		87,730	64.5	94.5	61.0
Sulfur	124,900					
S in Residues						
as S^o (recoverable)			29,500		23.6	
as Pyrite			0			
as Jarosite			0			
H_2SO_4			0			
SO_2 Emissions			190,800		76.4	

* Includes stockpiled residue

TABLE 6 HBMS **SMELTER THROUGHPUTS, GRADES & RECOVERIES**
Option 2 (Copper Inco Flash Furnace + Zinc Pressure Leach, Electrowin Process)

	SMELTER FEED		SMELTER OUTPUTS	RECOVERIES %		
	Inputs mty or oz/y	Grades % or oz/mt	mty or oz/y	Ore to Conc.	Conc. to Metal	Ore to Metal
Copper Plant						
Smelter Feed*	302,460					
Copper	67,560	22.3	64,740	91.2	95.8	87.4
Zinc	9,530	3.15	3,580	8.3	37.6	3.1
Silver	1,481,920	4.90	1,441,760	62.0	97.3	60.3
Gold	85,940	0.284	81,800	59.4	95.2	56.6
Sulfur	85,700	28.3	-	-	-	-
S in Residues	9,700					
as S^o			0			
as Pyrite			0			
as Jarosite			0			
H_2SO_4			140,000		48	
SO_2 Emissions			99,400		52	
Zinc Plant						
Concentrate Feed	132,160					
Copper	790	0.6	580	1.2	73.5	0.9
Zinc	66,700	50.5	65,370	78.0	98.0	76.4
Silver	249,470	1.89	220,310	11.9	88.3	10.5
Gold	6,910	0.052	5,930	5.1	85.7	4.4
Sulfur	39,200	29.7	-	-	-	-
S in Residues						
as S^o			32,700		83.5	
as Pyrite & sulfides			5,900		15.0	
as Jarosite			600		1.5	
H_2SO_4			0			
SO_2 Emissions			0			
Cu + Zn Plants						
Total Feed	434,620					
Copper	68,350		65,320	92.4	95.6	88.3
Zinc	76,230		68,950	86.3	90.4	78.0
Silver	1,731,390		1,662,070	73.9	96.0	70.9
Gold	92,850		87,730	64.5	94.5	61.0
Sulfur	124,900					
S in Residues						
as S^o (recoverable)			29,500		23.6	
as Pyrite			0			
as Jarosite			0			
H_2SO_4			140,000		36.6	
SO_2 Emissions			99,400		39.8	

* Includes stockpiled residue

TABLE 7 HBMS — SMELTER THROUGHPUTS, GRADES & RECOVERIES
Option 3 (GCM Copper Process + Zinc Pressure Leach, Electrowin Process)

	SMELTER FEED		SMELTER OUTPUTS	RECOVERIES %		
	Inputs mty or oz/y	Grades % or oz/mt	mty or oz/y	Ore to Conc.	Conc. to Metal	Ore to Metal
Copper Plant						
Concentrate Feed	289,790					
Copper	66,060	22.8	64,740	91.2	98.0	89.4
Zinc	7,650	2.64	6,890	8.3	90.0	7.5
Silver	1,431,260	4.94	1,316,760	62.0	92	57.0
Gold	83,430	0.288	75,090	59.4	90	53.6
Sulfur	83,400	28.8	-	-	-	-
S in Residues						
as S^o			67,900		81.4	
as Pyrite & sulfides			16,500		19.8	
as Jarosite			0			
H_2SO_4			0			
SO_2 Emissions			0			
Zinc Plant						
Zinc Plant Feed*	128,650					
Copper	790	0.6	580	1.2	73.5	0.9
Zinc	63,330	49.2	62,060	78.0	98.0	76.4
Silver	247,200	1.922	205,180	11.9	83	1.0
Gold	7,340	0.057	5,950	5.1	81	4
Sulfur	36,500	28.4				
S in Residues						
as S^o			30,300		83.0	
as Pyrite & sulfides			5,450		15.0	
as Jarosite			750		2.0	
H_2SO_4			0			
SO_2 Emissions			0			
Cu + Zn Plants						
Total Feed	418,440					
Copper	66,850		65,320	92.4	97.7	90.3
Zinc	70,980		68,950	86.3	97.1	83.8
Silver	1,678,460		1,521,940	73.9	90.7	67.0
Gold	90,770		81,040	64.5	89.3	57.6
Sulfur	119,900					
S in Residues						
as S^o (recoverable)			86,300		72.0	
as Pyrite & sulfides			21,950		18	
as Jarosite			750		0.6	
H_2SO_4			0			
SO_2 Emissions			0			

* Includes stockpiled residue

TABLE 8 HBMS

MODERNIZATION ALTERNATIVES
CAPITAL COSTS

ITEM	10^3 CDN DOLLARS (1983)		
	Zinc Pressure Leach	Inco Flash Smelter	GCM Copper Process
Materials Handling	4,700	7,900	9,000
Drying, Smelting Plant	-	63,900	-
Extraction Plant	24,000	-	48,300
Electrolytic Plant	-	-	47,500
Oxygen Plant	6,400	13,200	-
Utilities & Facilities	7,900	12,000	25,200
Acid Plant & Auxilliaries	-	30,000	-
TOTAL	**43,000**	**127,000**	**130,000**

INCREMENTAL OPERATING COSTS

PLANT AREAS AND COST COMPONENTS	OPTION 1 10^3 $ c/y	OPTION 2 10^3 $ c/y	OPTION 3 10^3 $ c/y
Mining Cost HBMS Ore	0	0	-736
Milling Cost HBMS Concentrate	0	0	-238
Cost of Custom Cu Concentrate	+137	+137	-1429
Cost of Custom Zn Concentrate	-4656	-4656	-7857
Concentrate Handling	-33	-33	-75
Total Mining/Milling	-4552	-4552	-10,335
Copper Circuit:			
Drying Plant - Total Labour	0	-79	-514
- Electricity	0	-413	-544
- Fuel Oil	0	-595	-595
- Other	0	-862	-369
Sub-Total	0	-225	-2022
Cu Roasters - Total Labour	0	-729	-729
- Electricity	0	-98	-98
- Coal/Propane	0	-986	-986
- Other	0	-507	-507
Sub-Total	0	-2321	-2321
Share Fuming Plant - Total Labour	0	0	-280
- Electricity	0	0	-144
- Coal	0	0	-637
- Other	0	0	-223
Sub-Total	0	0	-1284
Cu Extraction - Total Labour	0	-867	-407
- Electricity	0	+638	+1196
- Fuel Oil	0	-9970	-2533
- Propane	0	+1	-151
- Other	0	+370	-1347
Sub-Total	0	-9828	-3242
Acid Plant	0	+1526	0
Copper Refining	0	0	-18,550
Total Copper Cost	0	-10,848	-27,419
Zinc Circuit			
Zn Roasters - Total Labour	-1314	-1314	-1314
- Electricity	-64	-64	-64
- Fuel Oil	-420	-420	-687
- Other	-840	-840	-840
Sub-Total	-2638	-2638	-2905
Share Fuming Plant - Total Labour	0	0	-2146
- Electricity	0	0	-1104
- Coal	0	0	-4890
- Other	0	0	-1712
Sub-Total	0	0	-9852
Zn Extraction - Total Labour	-837	-837	-634
- Electricity	+83	+83	+112
- Fuel Oil	+483	+483	+483
- Other	0	0	+349
Sub-Total	-271	-271	+358
Zn Electrowin, Casting, Cd Plant	0	0	0
Total Zinc Cost	-2909	-2909	-12,399
Total Copper & Zinc Plants	-2909	-13,757	-39,819
Total Operation	-7461	-18,309	-50,154

TABLE 10 HBMS

MODERNIZATION ALTERNATIVES
PRODUCTS AND REVENUES

PRODUCTS	BASE CASE	OPTION 1	OPTION 2	OPTION 3
Copper (10^3 lb/y)				
Electrorefined	144,000	144,000	144,000	
Electrowon				144,000
Zinc Ingots (10^3 lb/y)	152,000	152,000	152,000	152,000
Silver (10^3 oz/y)				
in Cu Anodes	1,686.7	1,662.1	1,662.1	
in Residues				1,521.9
Gold (10^3 oz/y)				
in Cu Anodes	87.92	87.73	87.73	
in Residues				81.04
Lead Concentrate				
Pb (10^3 lb/y)	600	600	600	590
Ag (10^3 oz/y)	18	18	18	18
Au (10^3 oz/y)	0.17	0.17	0.17	0.17
Sulphur (S^o) (mty)	0	29,500	29,500	86,300
Sulphuric Acid (mty)	0	0	140,000	0
REVENUES ($c per lb or oz or mt)	10^3 CDN Dollars/year			
Copper (1.0625)				
Electrorefined	153,000	153,000	153,000	-
Electrowon*	-	-	-	153,000
Zinc (0.5625)	85,500	85,500	85,500	85,500
Silver				
in Cu Anodes (13.125)	22,138	21,815	21,815	-
in Residues (12.469)	-	-	-	18,977
Gold				
in Cu Anodes (687.5)	60,445	60,314	60,314	-
in Residues (653.1)	-	-	-	52,927
Lead Concentrate				
Pb (0.15)	90	90	90	90
Ag (12.469)	227	227	227	227
Au (653.1)	110	110	110	110
Sulphur (40/mt)	0	1180	1180	3452
Sulphuric Acid (-5 to -45/mt)	0	0	-700 to -6300	0
TOTAL	321,510	322,328	321,628 to 316,028	314,276

* It should be noted that it has not yet been proven that the quality & value of electrowon copper from option 3 is equivalent to electrorefined copper.

TABLE 11 HEMS
Basis: 65,000 mty Cu
69,000 mty Zn

MODERNIZATION ALTERNATIVES
SUMMARY TABLE

Incremental Outputs, Revenues & Costs	OPTION 1 ZPL Process		OPTION 2 ZPL & Inco Flash		OPTION 3 ZPL & GCM Process	
	oz/y or mty	10^3 $c/y	oz/y or mty	10^3 $c/y	oz/y or mty	10^3 $c/y
Copper & Zinc	0	0	0	0	0	0
Silver (oz/y)	-24,600	-323	-24,600	-323	-164,800	-3,161
Gold (oz/y)	-190	-131	-190	-131	-6,880	-7,518
Pb/Ag Concentrate	0	0	0	0	0	0
Sulphur (mty)	+29,500	+1,180	+29,500	+1,180	+86,300	+3,452
Sulphuric Acid (mty)	0	0	+140,000	-700 to -6,300	0	0
Annual Revenues*		+726		+26 to -5574		-7,227
Annual Operating Costs		-7,461		-18,309		-50,154
Total Annual Operating Surplus		+8,187		+18,335 to +12,735		+42,927
Capital Costs 10^6 $C		43		170		173
SO_2 Emissions Actual (mty) Reduction (mty % Reduction	190,800 67,200 26		99,400 158,600 61		0 258,000 100	

* Based on prices shown in Table 10